Synthesis of Nanostructures and Study of Ferroelectric Phenomena at the Nanoscale

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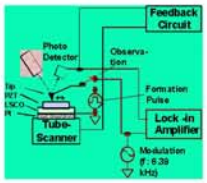
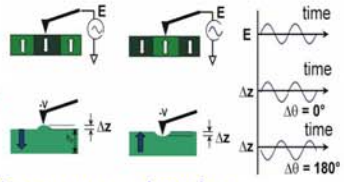
Motivation

Understand ferroelectric phenomena at the nanoscale using nanostructures based on ferroelectric thin films

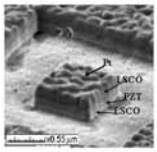
Major Accomplishments

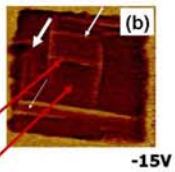
Study of ferroelectric domain switching via AFM Piezoresponse

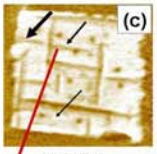




Piezoresponse Imaging

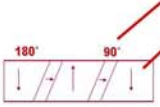




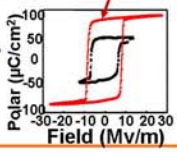


-15V DC

13 V DC

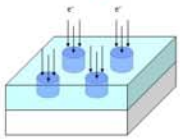


High polarization resulting from 90 ° domain motion

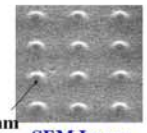


With Ramesh (Uof C-Berkeley)

Development of PZT nanocapacitors via e-beam lithography and dip-pen fabrication technique and characterization of polarization switching via AFM piezoresponse imaging

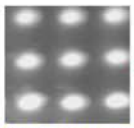


E-beam lithography at ANL-CNM

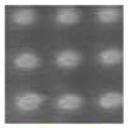


120 nm cell

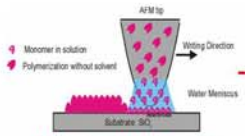
SEM Image



AFM Topo Image



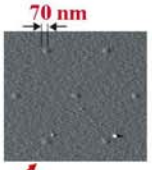
AFM Piezo Image



Dip-pen bottom-up fabrication of PZT nanocapacitors

(With Dravid at Northwestern U.)

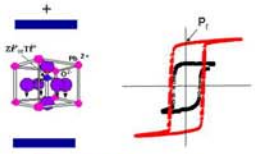
Anneal 650° C 10 mins



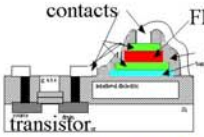
SEM Image

Impact

Fabrication of micro and nanocapacitors and understanding of ferroelectric phenomema at the nanoscale is critical to the current commercialization of low-density (to ~ 1MB) and development of next generation high-density non-volatile ferroelectric memories (FERAMS)



Up-down stable remanent polarization enables FeRAM

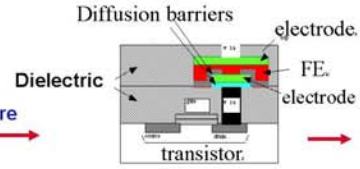


Low density FeRAM architecture

Present

FeRAM Smart Cards
(In the market now:
100 millions microchips/year
Made by Matshusita-Panasonic)

Future



High-density FeRAM architecture

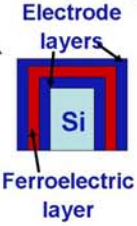
Stand -alone FeRAM e.g., computers

Embedded FeRAM e.g., cell phones

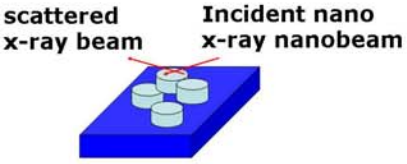
Future Work

Investigation of new Pb-free ferroelectric materials ($BiFeO_3$) via synthesis of thin films and characterization of composition-microstructure property relationships

- Development of 3-D ferroelectric nanocapacitors
- Studies of ferroelectric phenomena (e.g. polarization switching, domain dynamics) at the nanoscale
- integration of ferroelectric nanocapacitors with Si platform for high-density FERAMs



Explore impact of nanoscale dimensions on ferroelectric phenomena using synchrotron X-ray nanoprobe at the CNM



Synchrotron X-ray *in situ studies performed* within the ANL-Center for Nanoscale Materials

"Dynamics of Ferroelastic Domains in Ferroelectric Thin Films", V. Nagarayan, A. Roytbourt, A. Stanishevsky, S. Prasertchoung, T. Zhao, L. Chen, J. Mengailis, O. Auciello, and R. Ramesh, Nature-Materials 2 (2003) 43-47.

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